Applications of high-precision GNSS solutions in the economy

United Nations

Eleventh Meeting of the International Committee on Global Navigation Satellite Systems (ICG-11) and the 17th Meeting of the Providers' Forum,

6 – 11 November 2016, Sochi, Russian Federation

Experts Seminar on Applications, 07 November 2016.

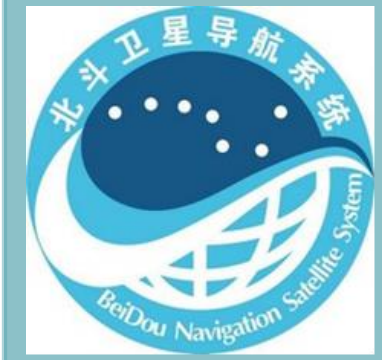
Andrey Kupriyanov "GLONASS/GNSS Forum Association"

GLOBAL NAVIGATION SATELLITE SYSTEMS

GLONASS

GPS

BEIDOU



GALILEO

REGIONAL NAVIGATION SATELLITE SYSTEMS

QZSS

IRNSS

SBAS (Satellite Based Augmentation System)

EGNOS

WAAS

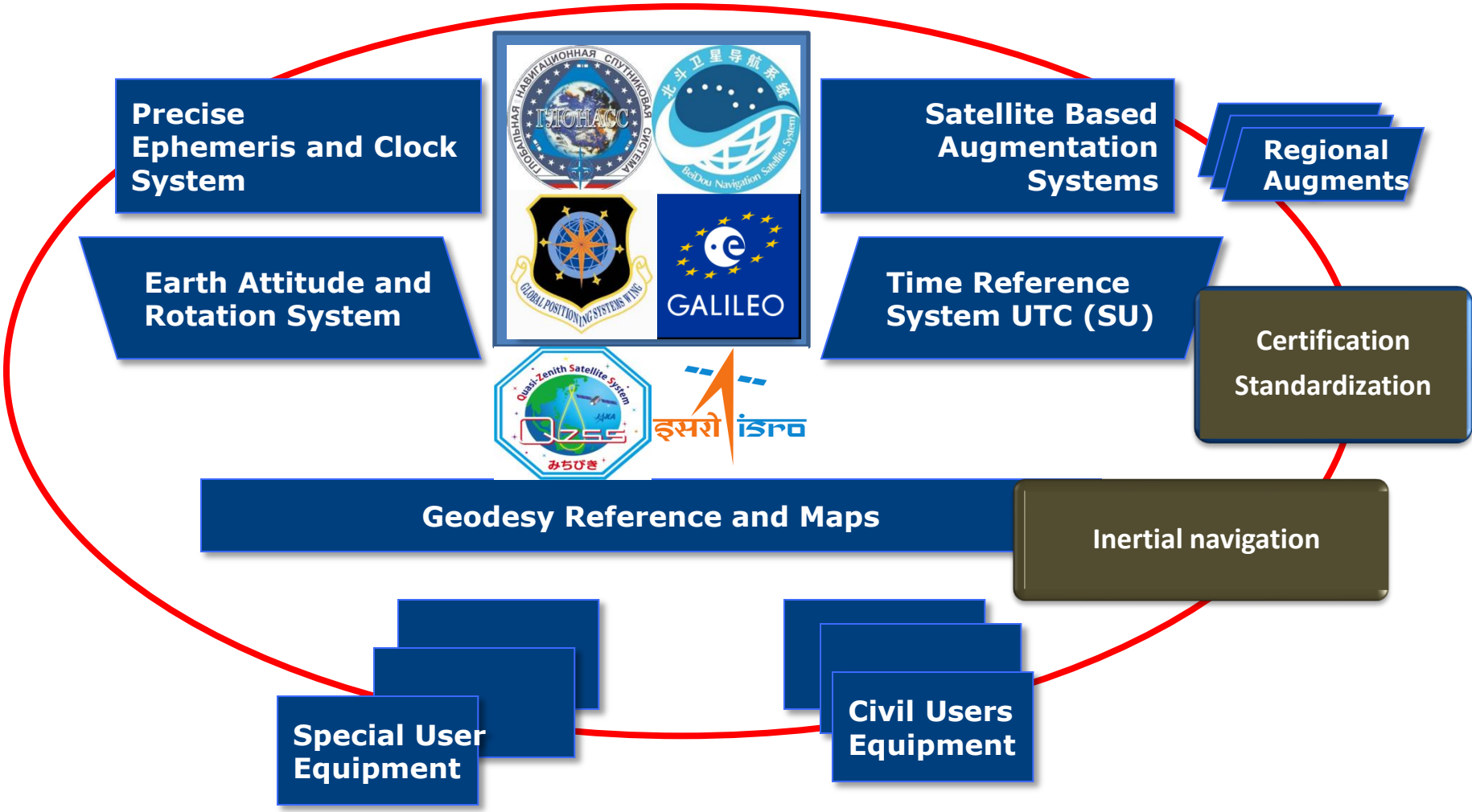
SDKM

GAGAN

MSAS

GLOBAL DIFFERENTIAL CORRECTION SYSTEMS

Synergy of performance and requirements



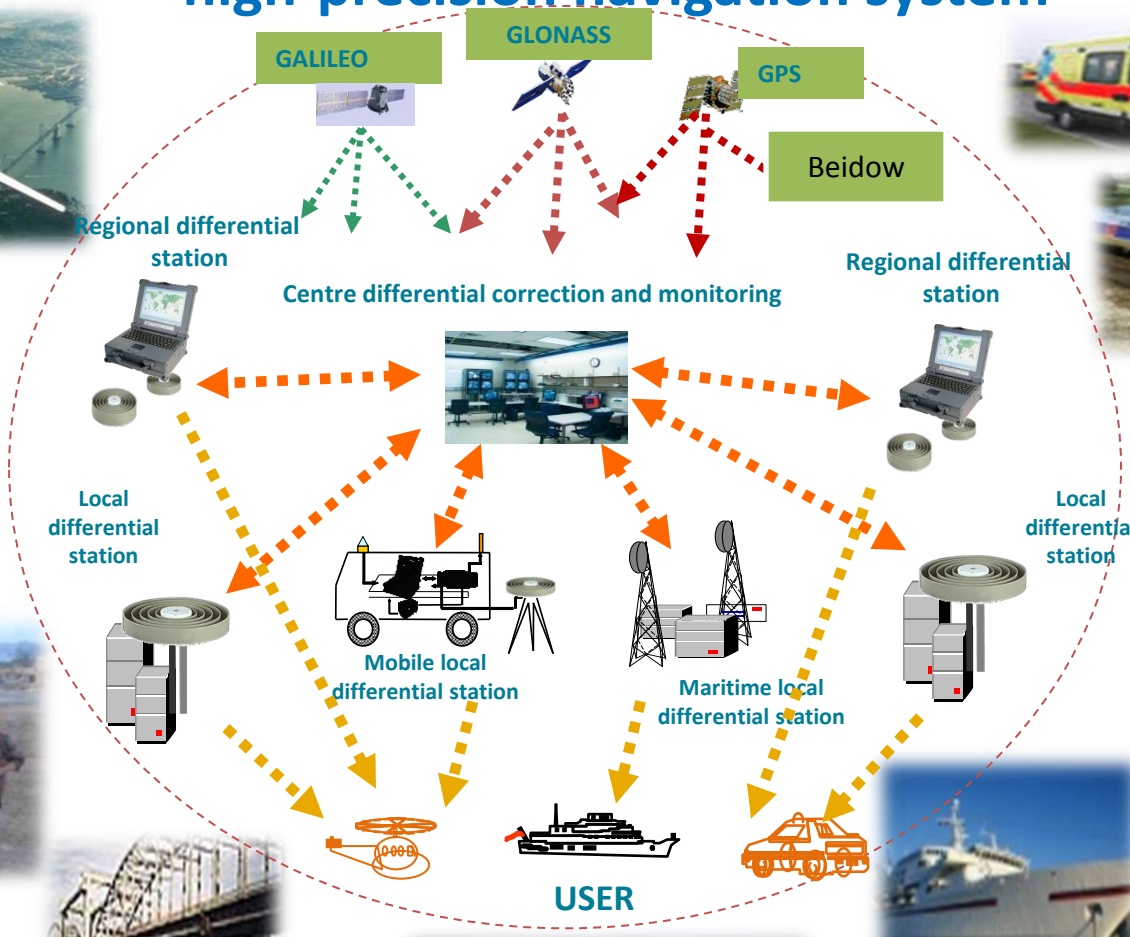
GNSS Application Sphere

Transport	Geodesy, cartography, cadastre	Construction	Mining	Agriculture
Inventory, management of territories	Monitoring of natural and technogenic processes	Space researches	Science	Communication
Trade	Power industries	Forestry, hunting	Fishery	Sports, tourism
Public health	Insurance	Policing	Emergency response	Social services

GNSS Application Sphere

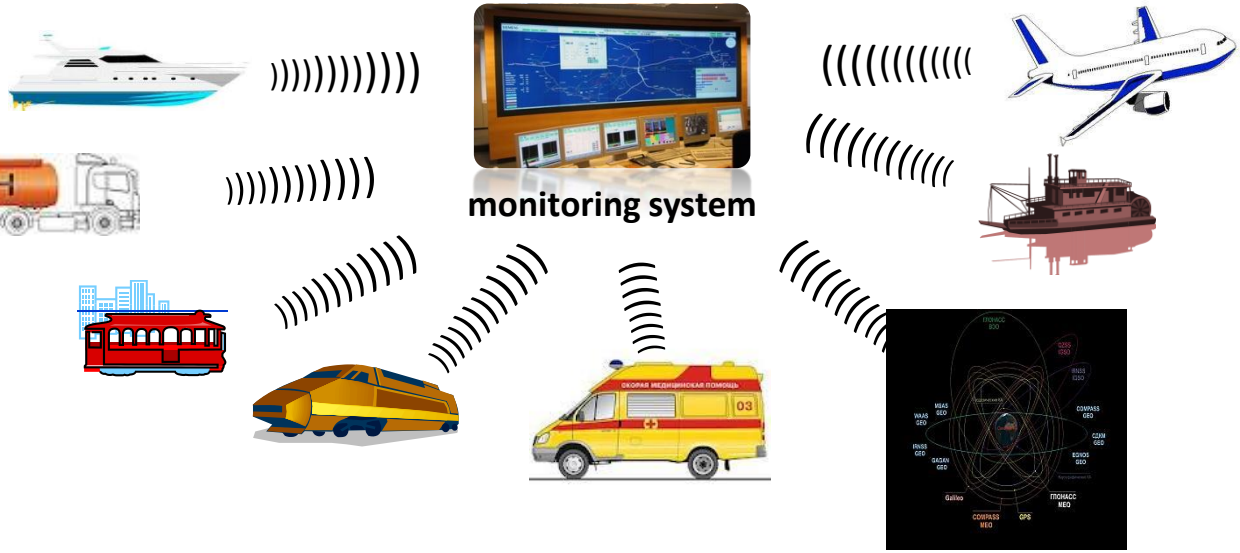
The next level of mass service – precision positioning

The development of ground infrastructure of high-precision navigation system



GNSS Application Sphere

GNSS TECHNOLOGIES ON TRANSPORT



Including :

Monitoring municipal, special transports	Traffic Monitoring, overcharge	Control of modes of working and rest of drivers

transportation of passengers

transportation of dangerous goods

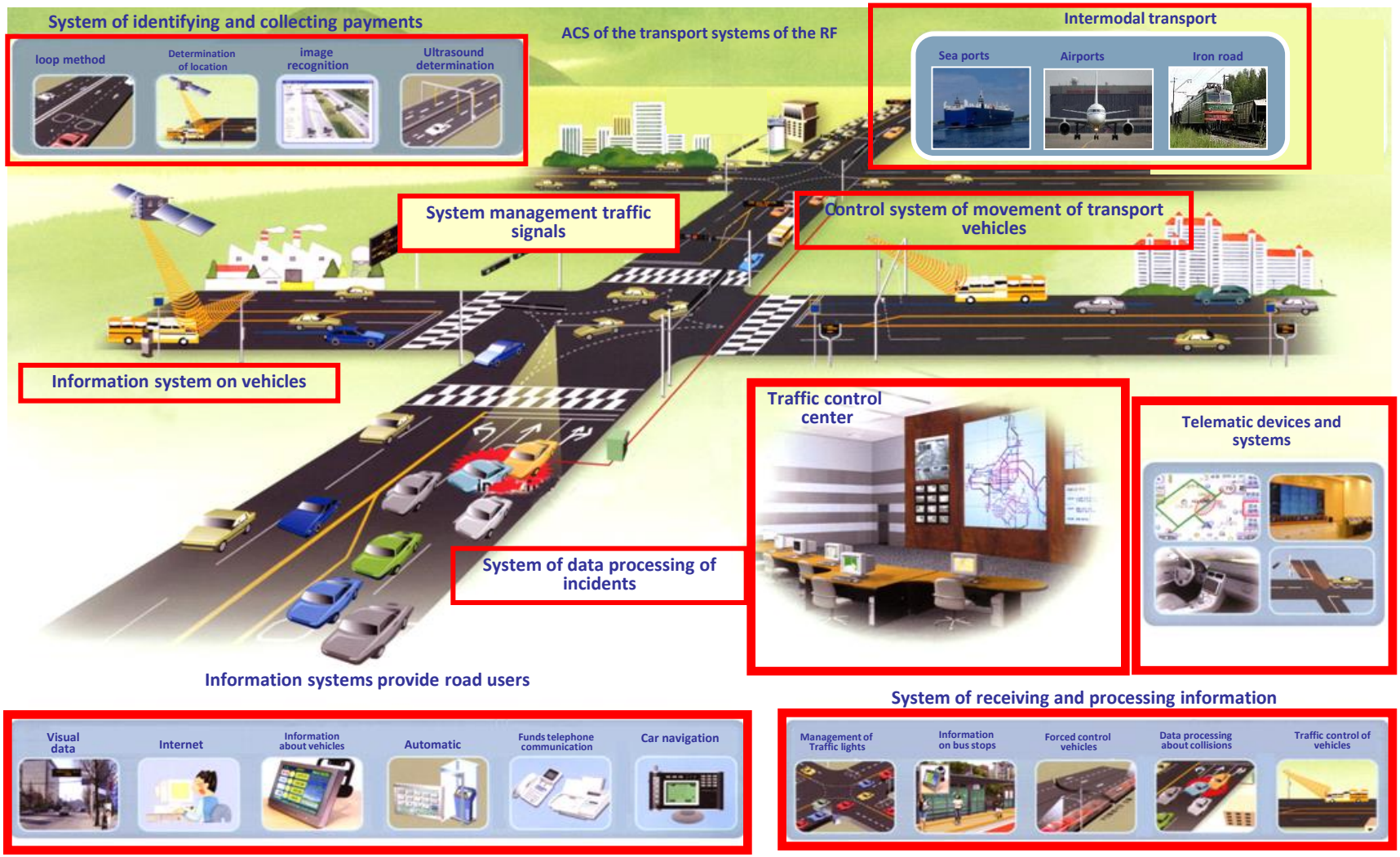
heavy lift

system of toll roads

tachographs with GNSS technologies

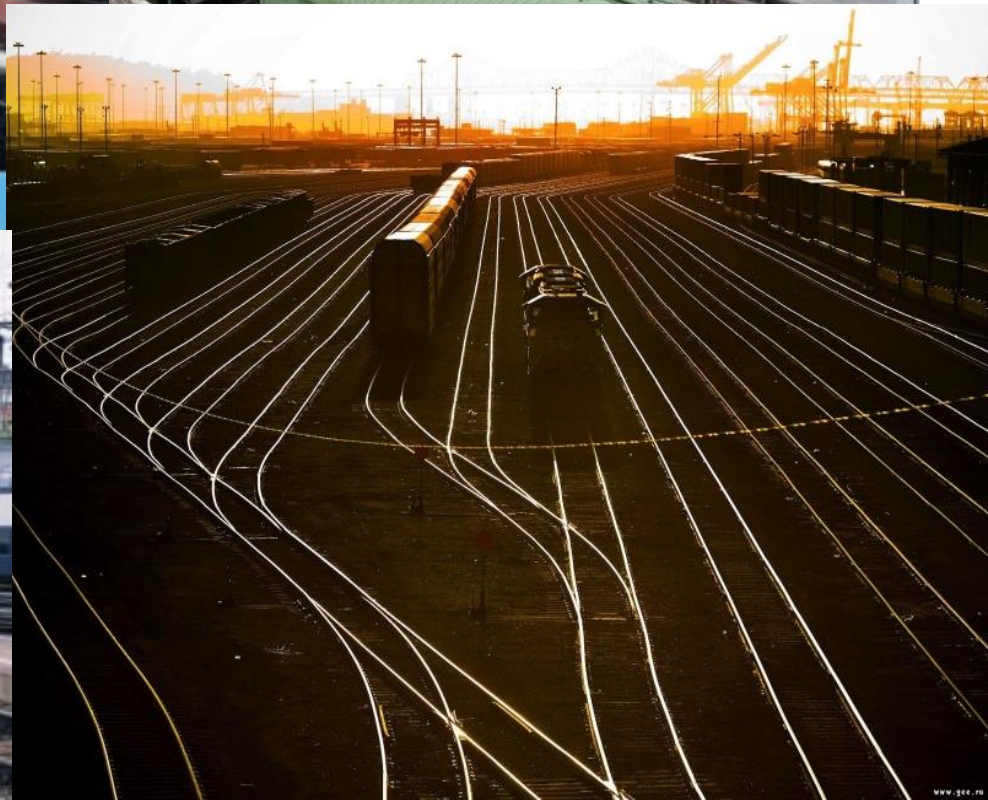
GNSS Application Sphere

Intelligent Transport Systems



Increasing Informational content coordinate and time providing rolling stock

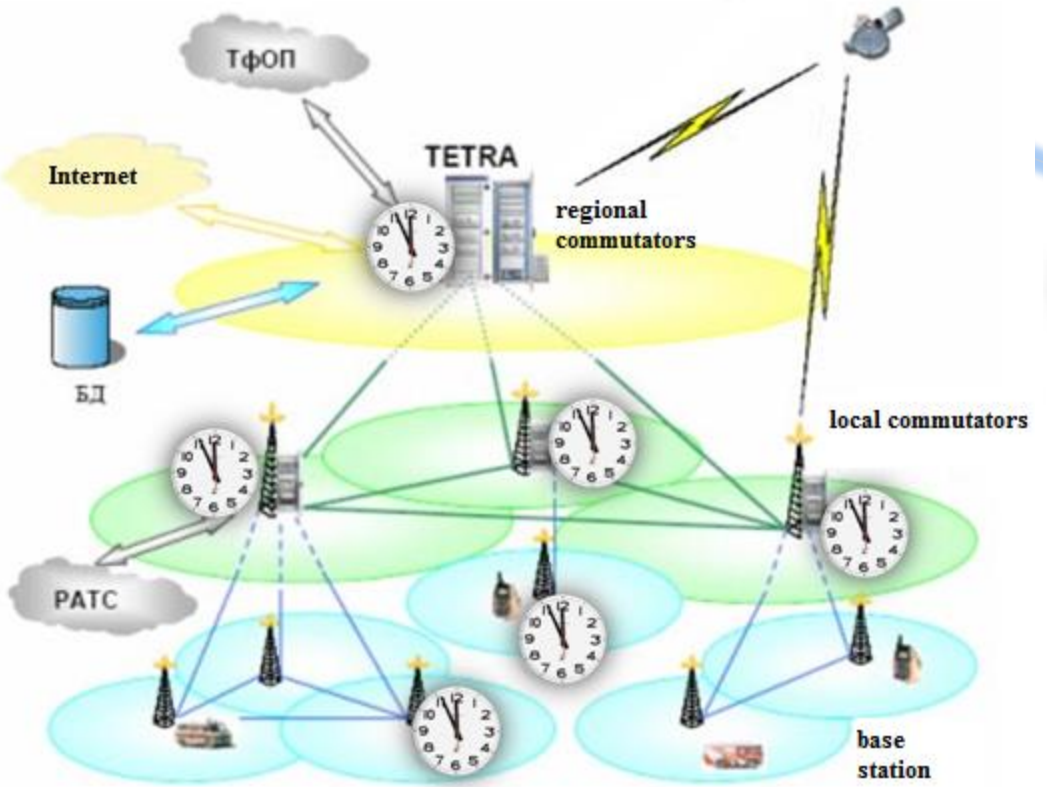
High-precision monitoring of objects of transport infrastructure, keeping and creating united digital cartographical basis

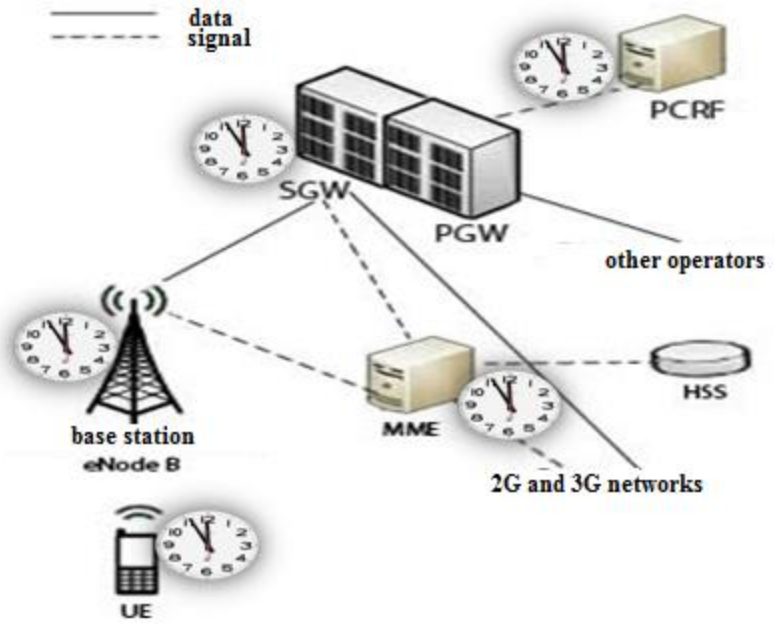


GNSS Application Sphere

Synchronization of communications networks

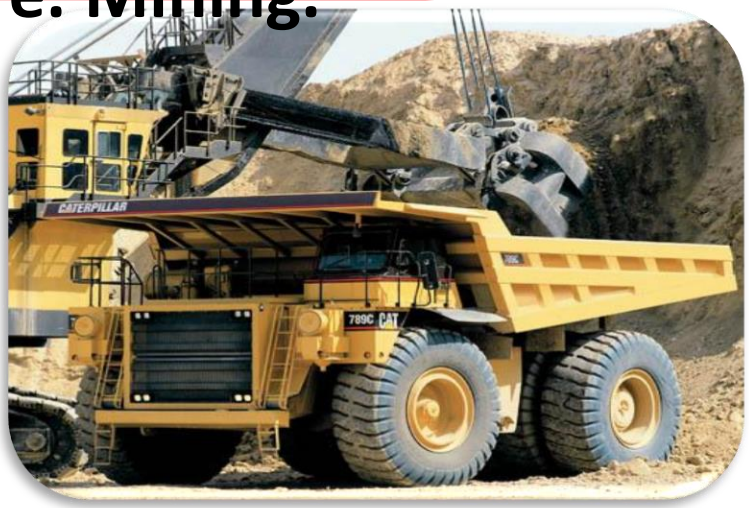
Structure of a cellular network of the standard 4G (LTE)





GNSS Application Sphere

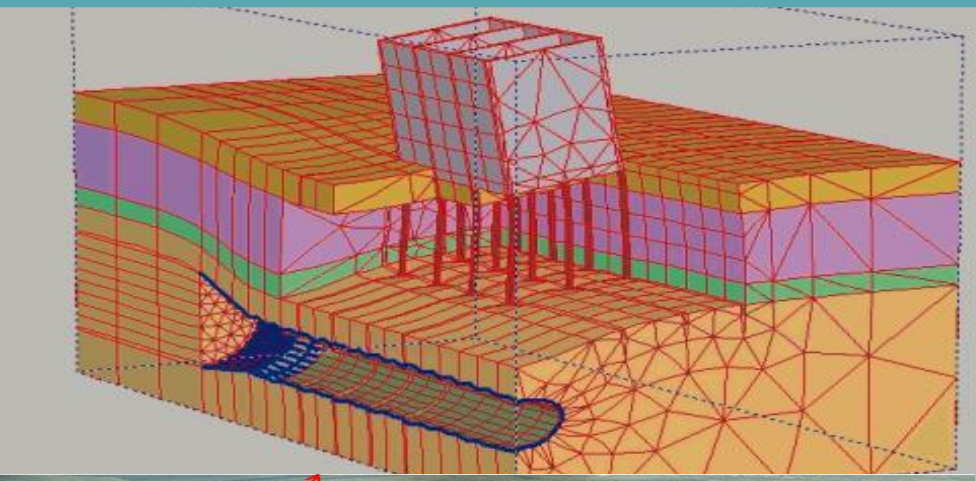
Precision agriculture. Mining.

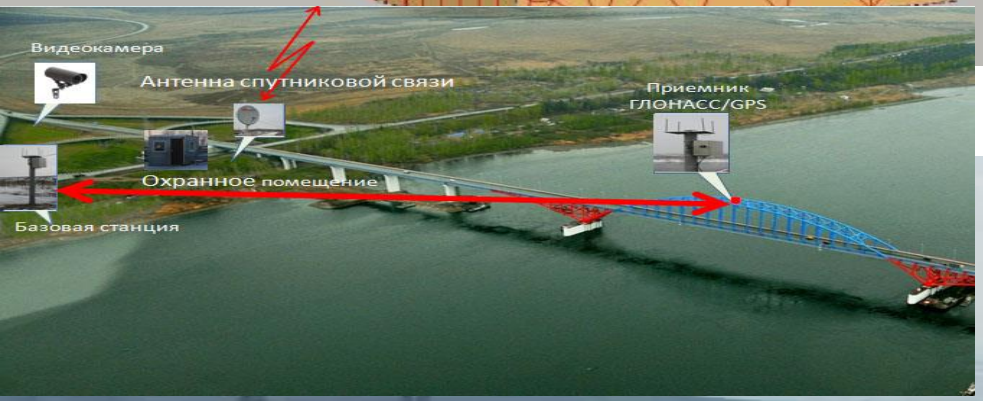


RTK is the main open cut mining GNSS technology

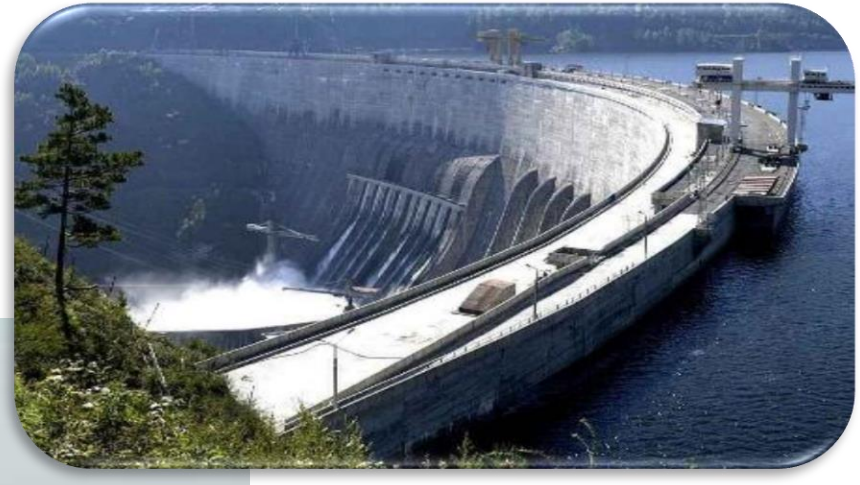
-Precision agriculture develops intensively in private sector using local differential networks, precision steering systems can now run on commercial market.

GNSS Application Sphere



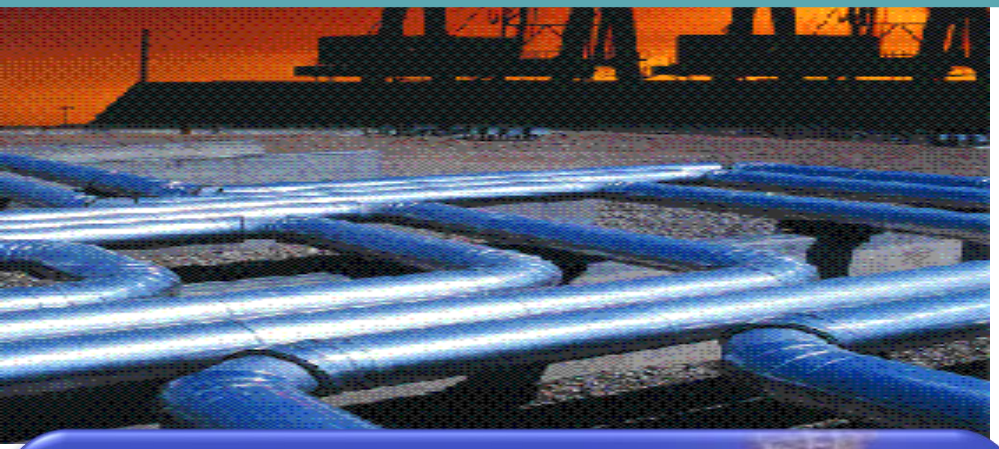


GNSS monitoring systems of buildings, bridges, dams - Precision control system using local reference systems, data transmission systems, software analysis for decision making



Unnoticed in time deformation of the construction may result into cracks and its subsequent collapse

GNSS Application Sphere



Direction of commercial high-precision applications of GNSS technology and equipment :

-monitoring of ground infrastructures, oil and gas pipelines, geophysical survey and other work on the continental shelf

-machine control - road construction with centimeter accuracy, using technology and real-time reference stations, digital maps

Since the late 80s commercial satellite equipment and technology for maritime and ground navigation, survey. Maritime and aviation application were under IMO and ICAO requirements and regulations.

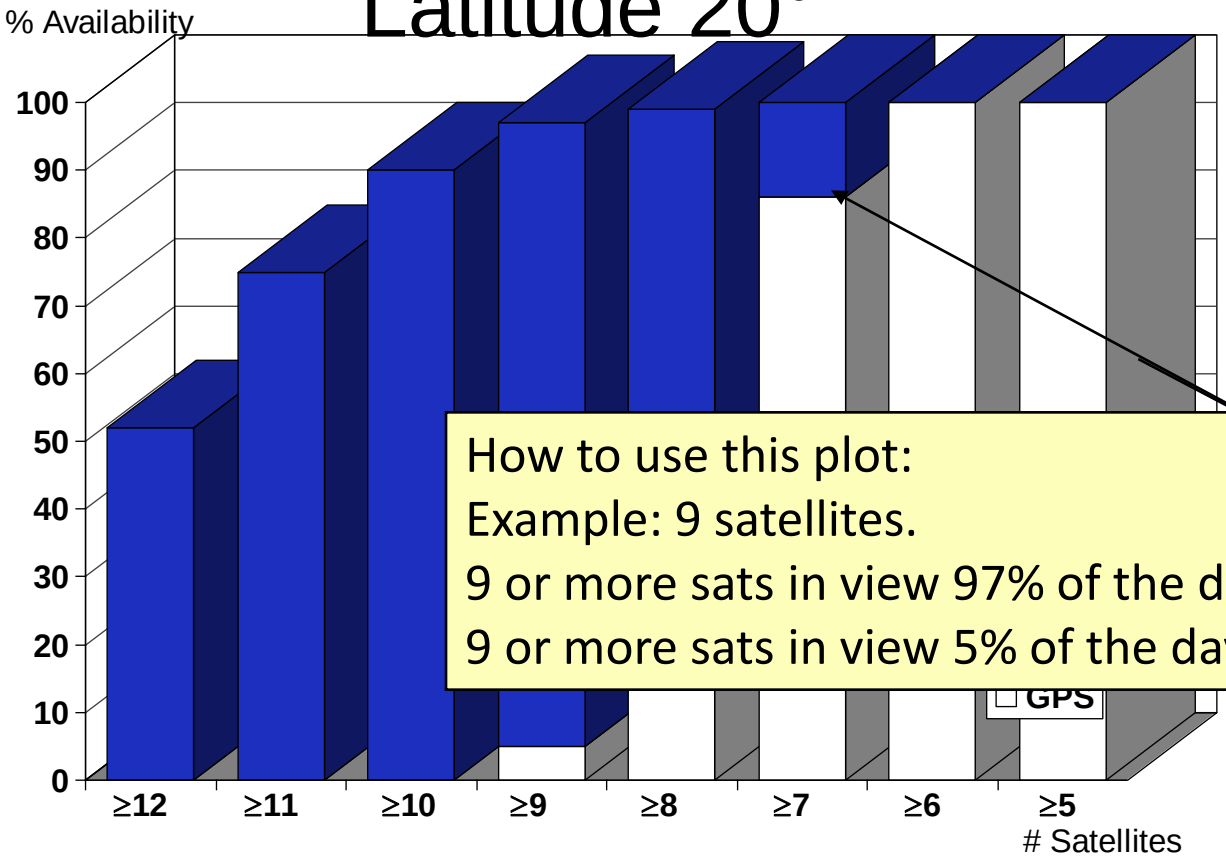
Commercial application of precision technology and equipment were first of all in survey, cadastre, land and ground infrastructure inventory. The major sector of application were oil&gas, survey and mining.

The methods of field applications were static, pseudo kinematic.

LIGHT
POS
NAV
COURSE
AUX
ON/OFF
WPT
DR
CLEAR
MAGELLAN

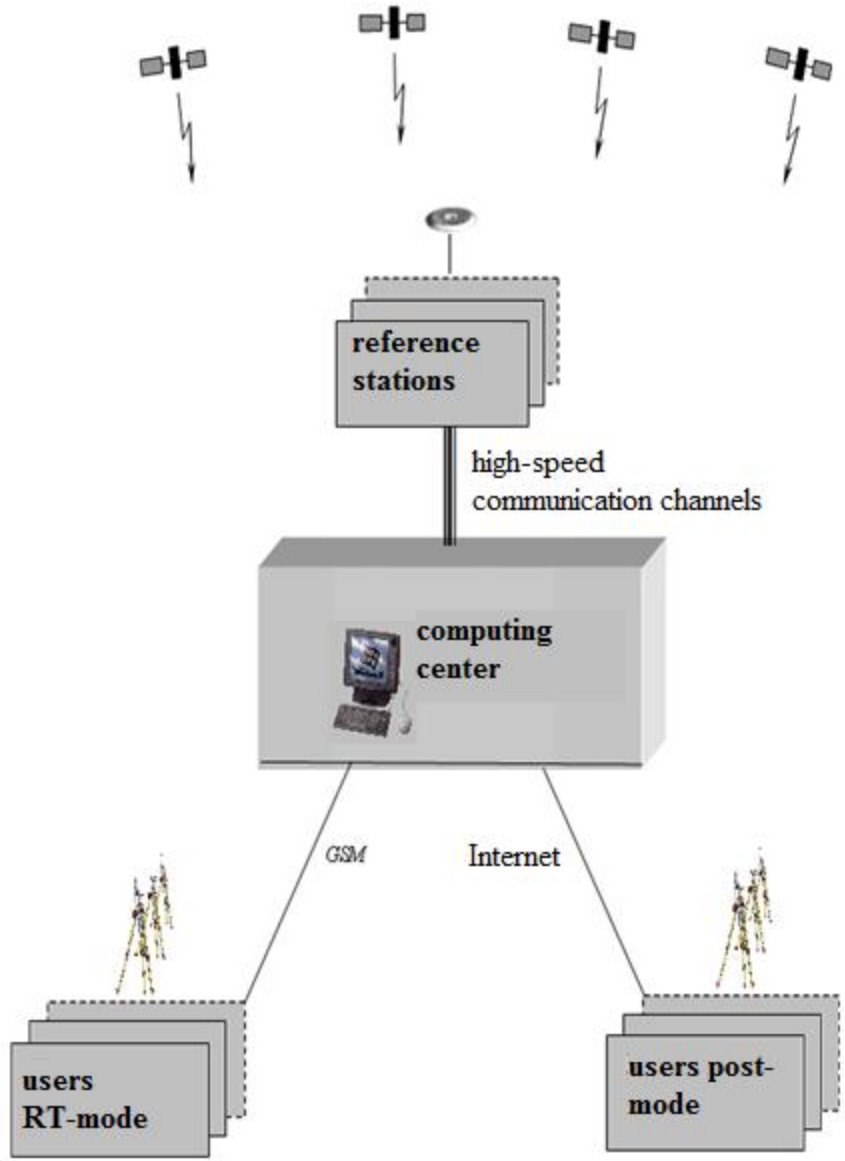
Ashtech
ProMark2
IN
OUT
ESC
ENTER
MENU
GOTO
Ashtech
PRECISION PRODUCTS

Latitude 20°



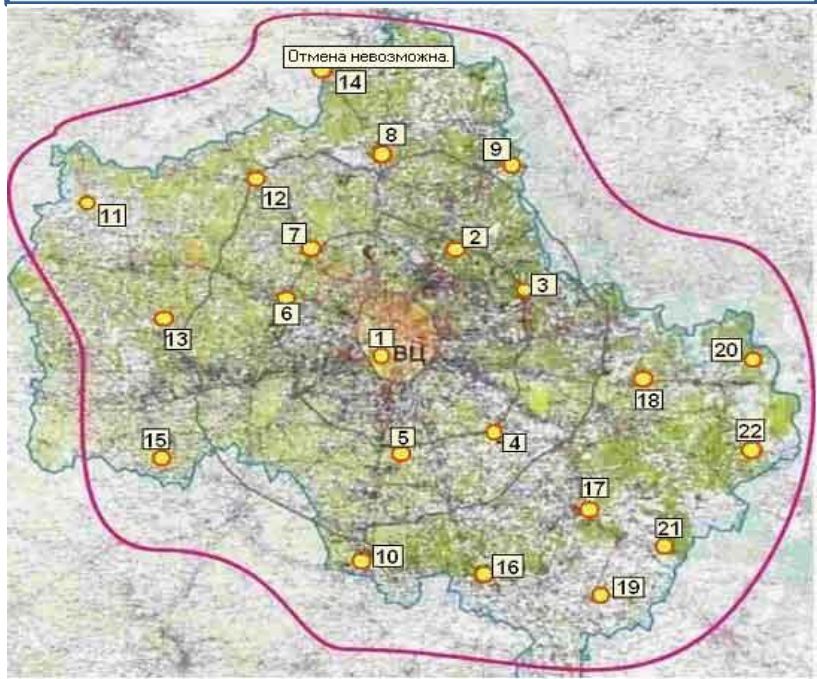
How to use this plot:
Example: 9 satellites.
9 or more sats in view 97% of the day, with GPS+GLONASS
9 or more sats in view 5% of the day, with GPS-only

Almanac from 9/15/97. 25 Healthy GPS Sats, 40 Healthy GPS+GLONASS Sats
8 Day simulation, 10 degree mask angle.



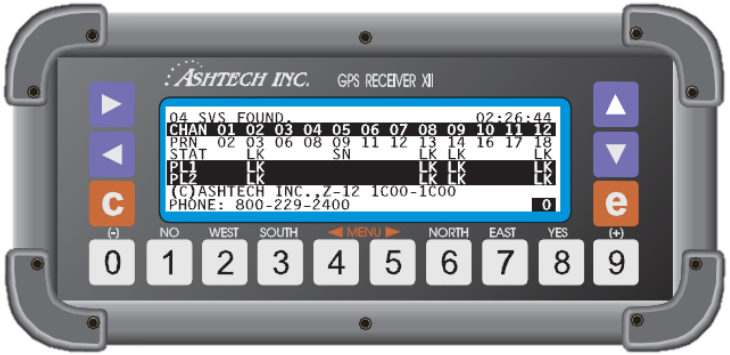
The next step was
Development, improvement of technology equipment for commercial application
- RTK-kinematics in real time, kinematics with moving base
base stations, transmission of differential corrections

Development of commercial (regional, local) reference networks for various applications based on GLONASS and GPS signals



GNSS Equipment Ergonomics Evolution

Ashtech Z-12 GPS Receiver

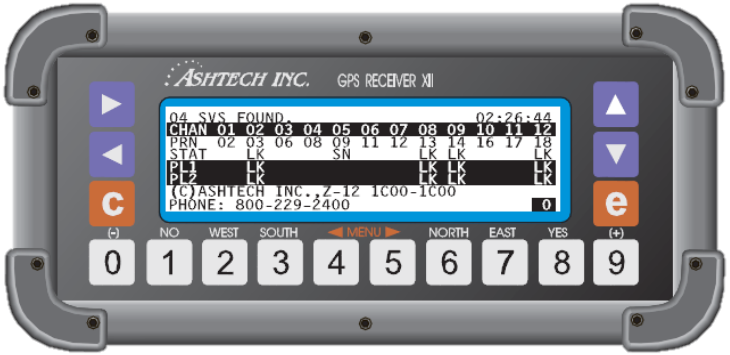


NovAtel PwrPak7

4.0 kg	8/1	0.5 kg
21.6 x 20.3 x 9.9 cm	4/1	14.7 x 14.5 x 5.3 cm
power consumption 21W	12/1	power consumption 1.8W

GNSS Equipment Ergonomics Evolution

Ashtech Z-12 GPS Receiver



GPS
L1, L2

12 Channel

Real-Time Differential Position
< 1 m

NovAtel PwrPak7

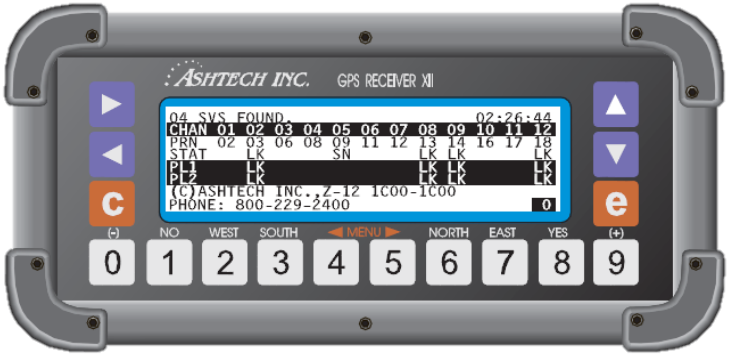
GPS L1, L2, L5; GLONASS L1, L2, L3, L5; BeiDou B1, B2, B3; Galileo E1, E5 AltBOC,E5a, E5b, E6; IRNSS L5; SBAS L1, L5; QZSS L1, L2, L5, L6

555 Channel

SBAS (60 cm); DGPS (40 cm); PPP TerraStar-L (40 cm); PPP TerraStar-C (4 cm); RTK (1 cm + 1 ppm)

Survey GNSS Equipment Evolution

Ashtech Z-12 GPS Receiver



1995

NovAtel PwrPak7

2016

Static, Pseudo-Kinematic Survey Accuracy:

5 mm + 1 ppm

3 mm + 0.5 ppm

Multi – GNSS

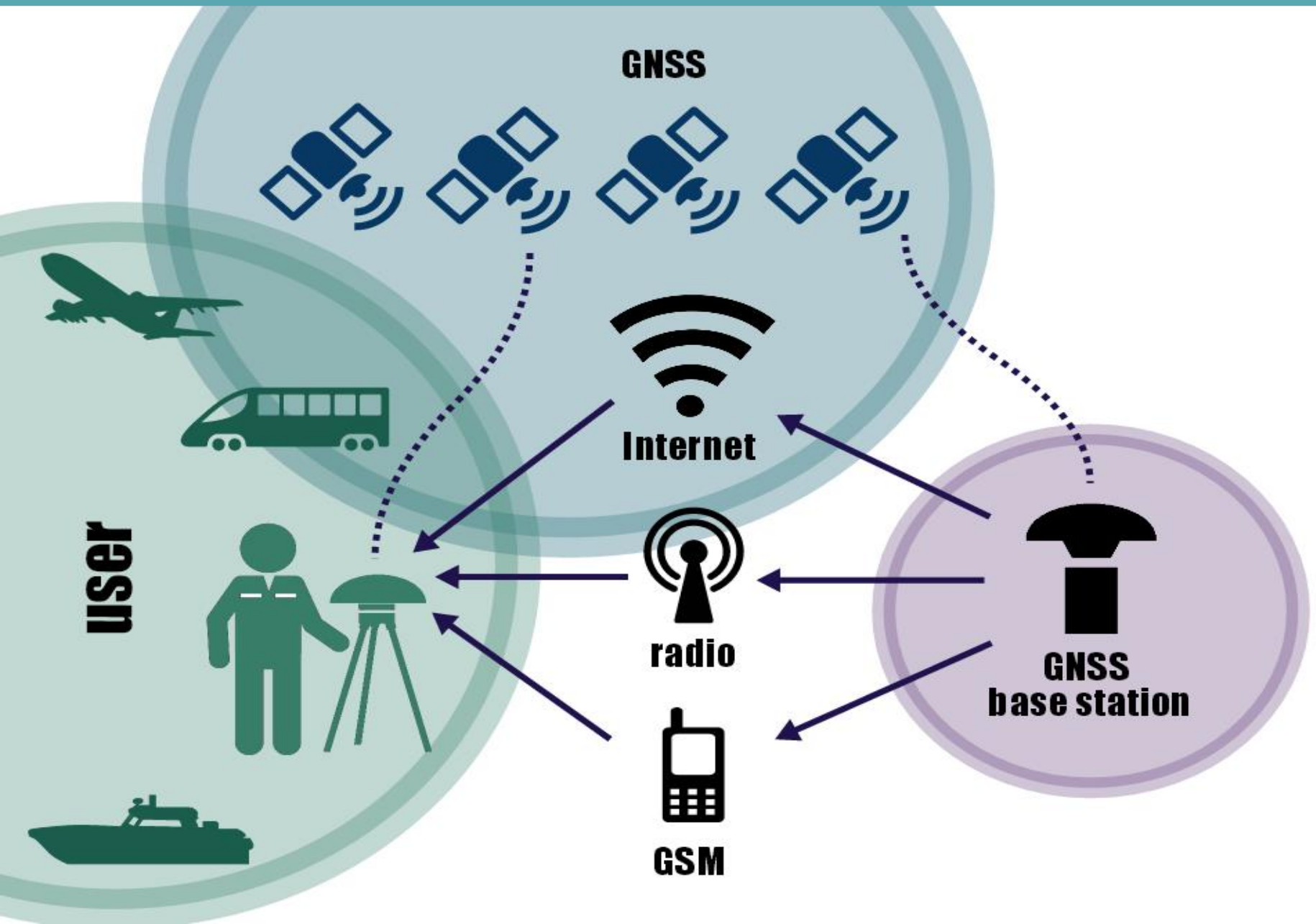
- More Satellites
- Improved PPP convergence
- More pierce points for atmospheric sounding
- Decorrelation of height, clock, troposphere
- Improved Signals
- Less multipath
- Increased robustness (scintillation, weak signals)
- Stable clocks
- Improved Real-time PPP
- Orbit improvement / prediction
- Diversity
- Different orbital periods and commensurabilities
- Decorrelation of estimated parameters (orbits, Earth rotation)

IGS-RTS spurring innovation...

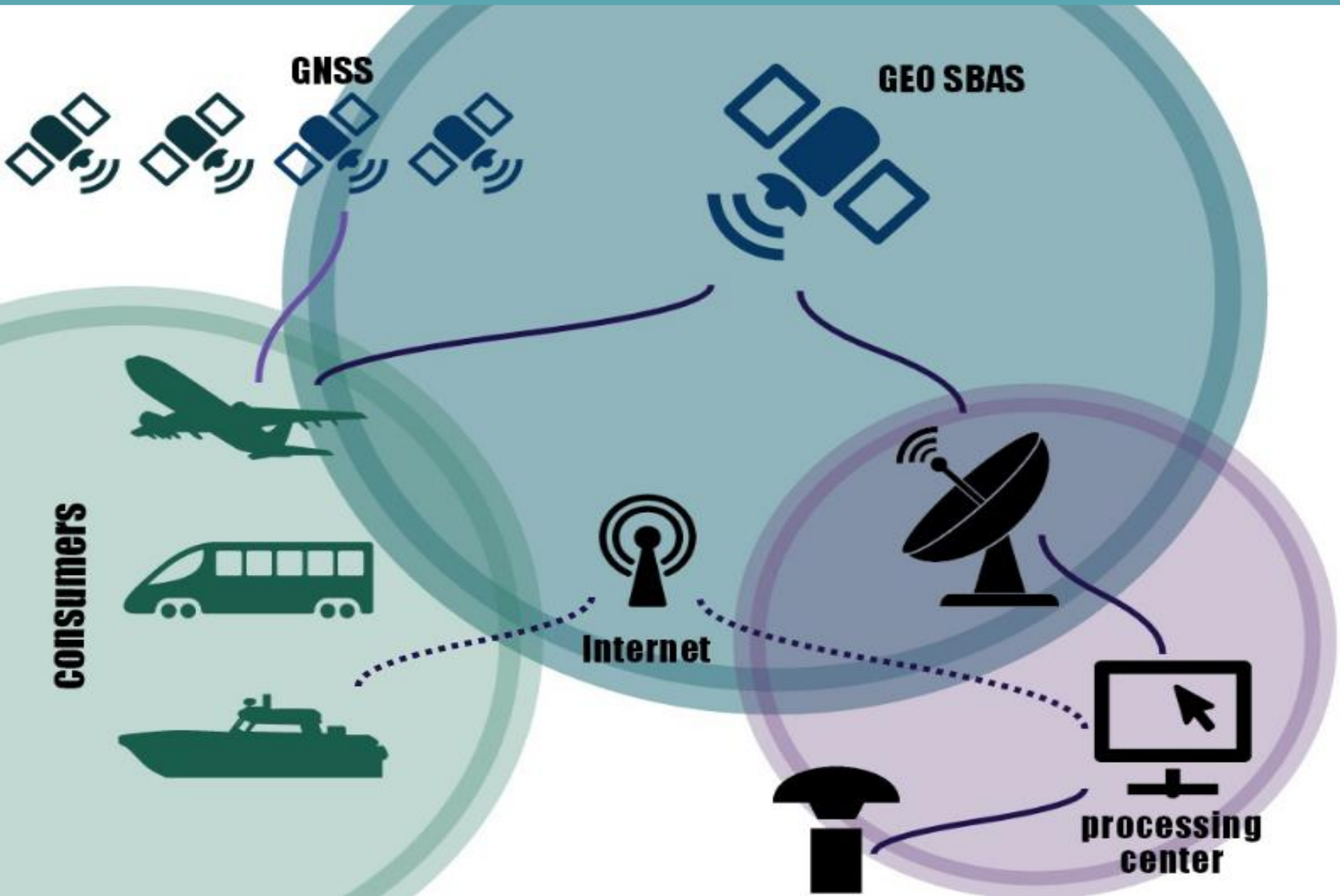
- Geohazard... seismic displacements, tsunami prediction
- (Near-)real-time comparison of UTC(k)'s... time transfer
- IGMA parameter estimation... orbits, clocks, etc
- Atmospheric remote sensing, meteorology
- Precise orbit determination
- Geodesy, datum studies/monitoring, kinematic positioning
- Buoys, wave height measuring, hydrography
- Surveying, mapping, UAV platforms, agriculture, etc
- Performance statistics... intercomparisons, RTK v PPP v SBAS
- Testing, demonstrations, investigations... manufacturers, academic
- Low-cost GNSS receiver studies
- Intelligent Transport System
- Outdoor robotics, wearables, IoT
- Education

(Chris Rizos, Steve Fisher, Ruth Neilan IGS W-S Sydney)

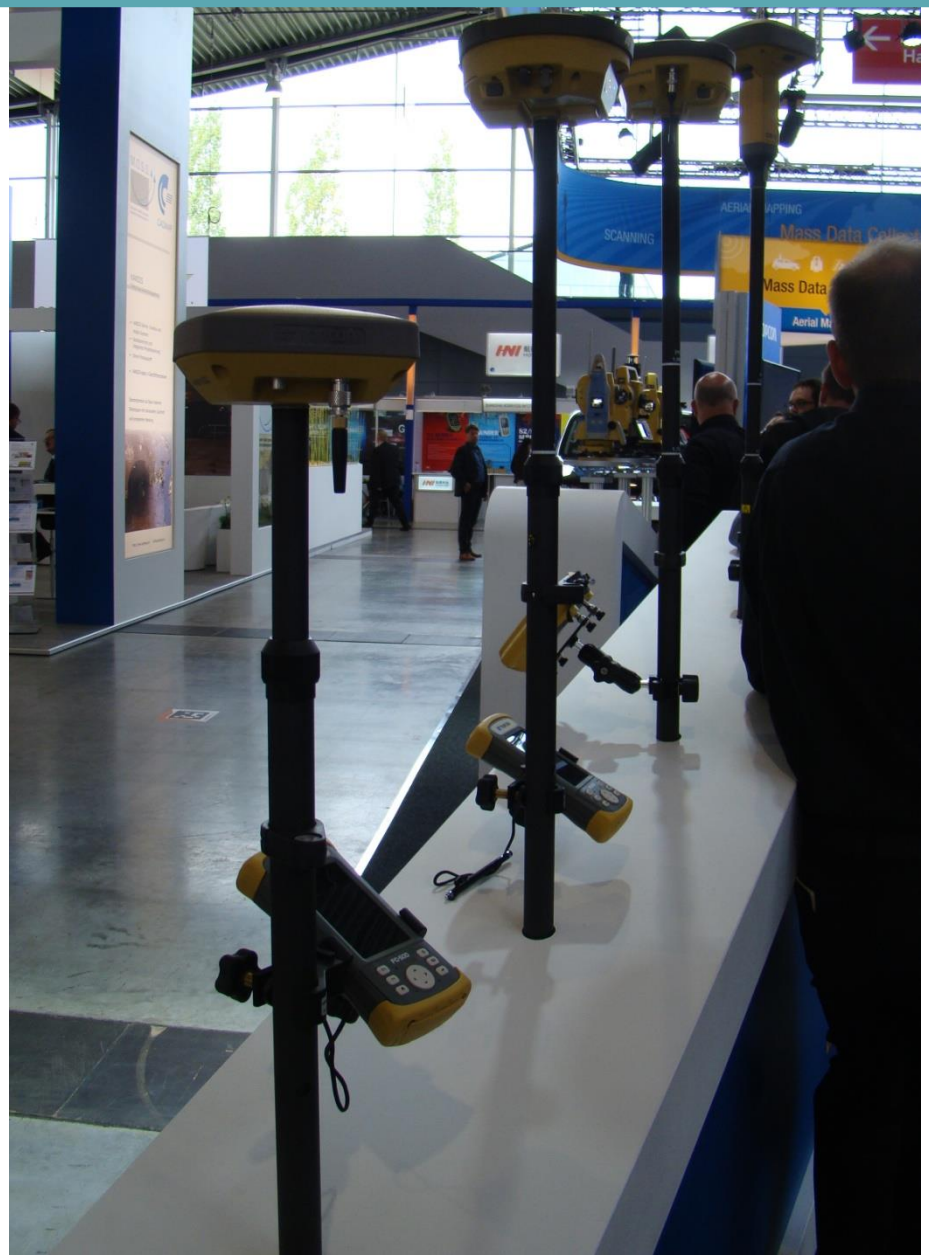
Positioning Technology: Real-Time Kinematics



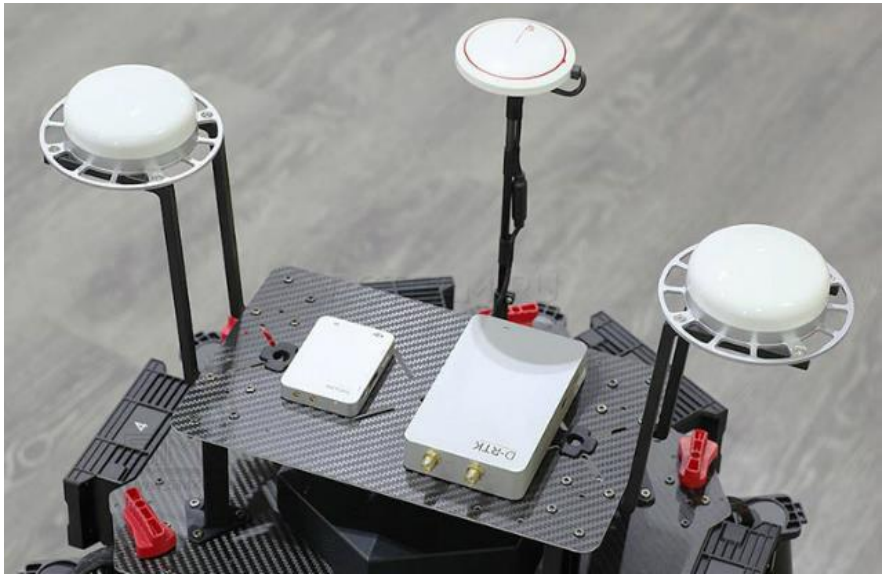
Positioning Technology: Real Time PPP



High-Precision GNSS Equipment - Mass Product



High-Precision Solutions as Part of Complex Systems

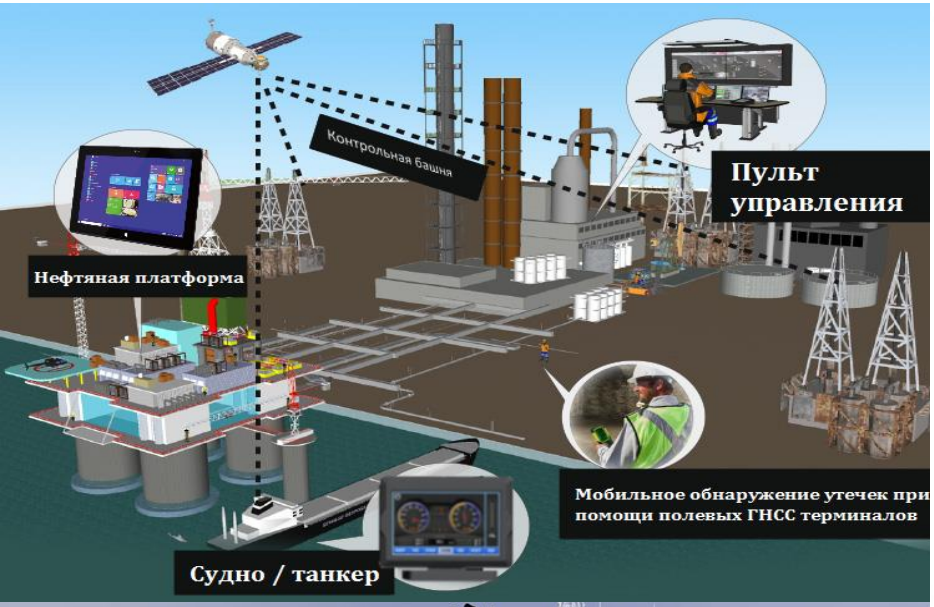


Integration of High-Precision Solutions into Mobile Devices

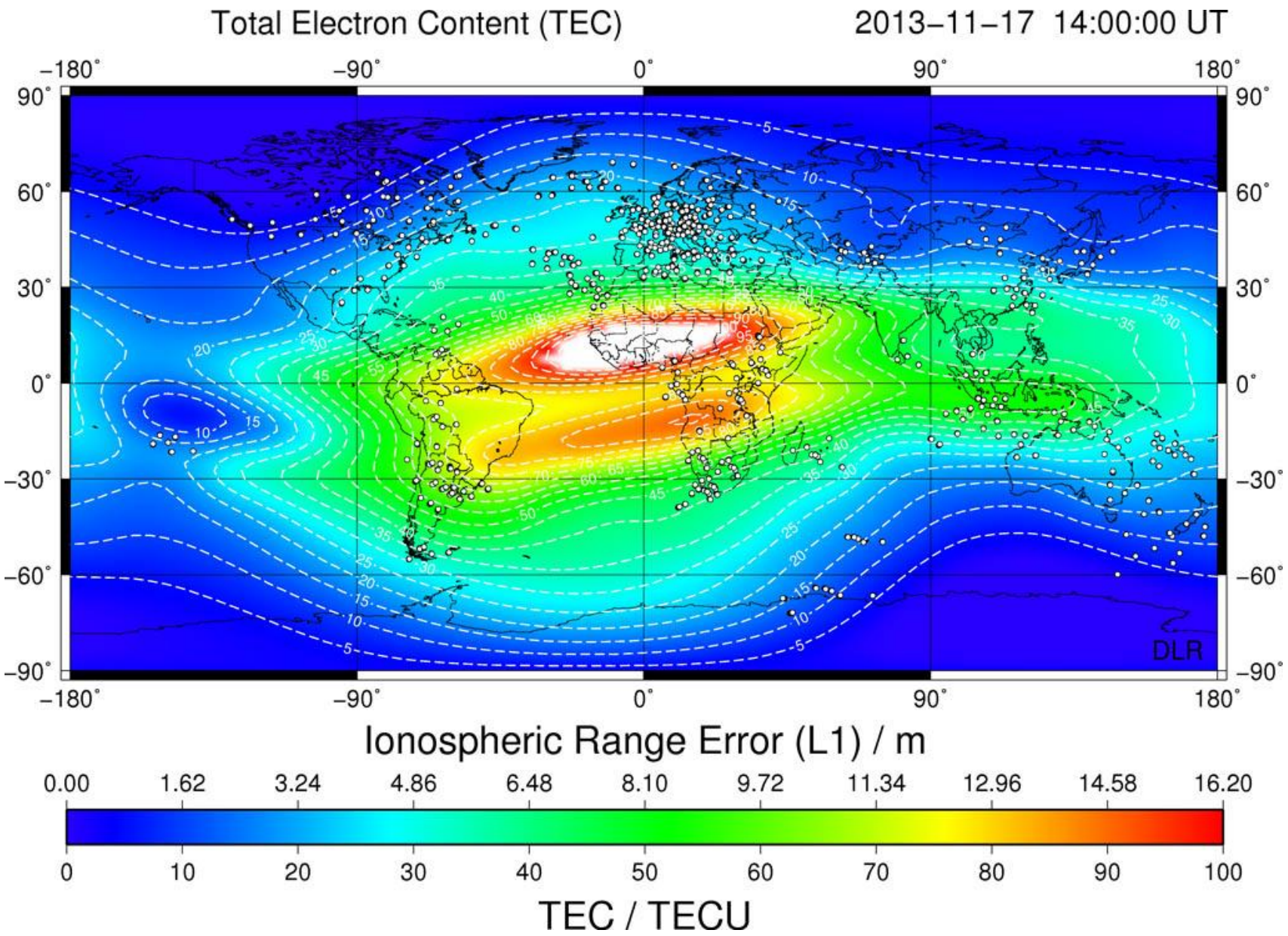
Integration of High-Precision Solutions into Mobile Devices

Integration of High-Precision Solutions into Mobile Devices

Sphere of Implementation of High-Precision Solutions into Mobile Devices

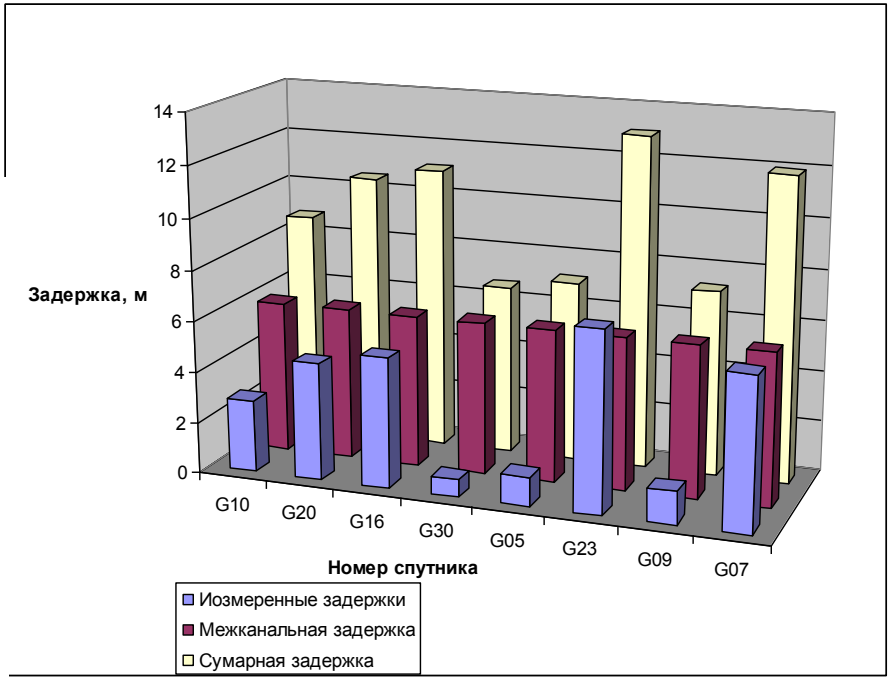


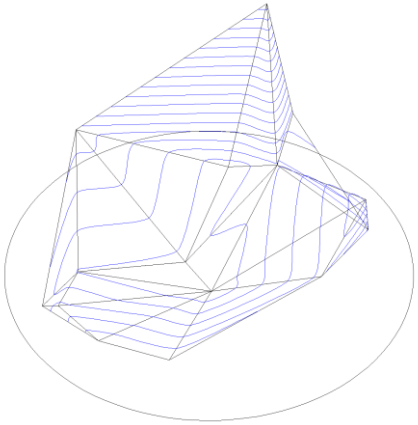
Atmosphere Anomalies Detection

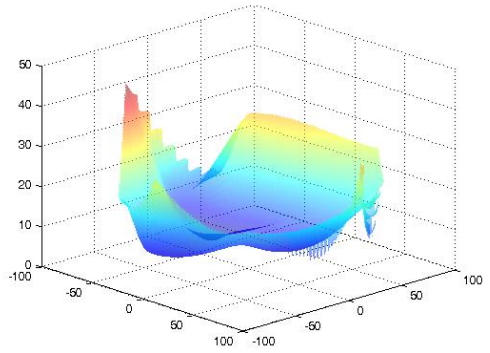


Atmosphere Anomalies Detection

GPStation-6™







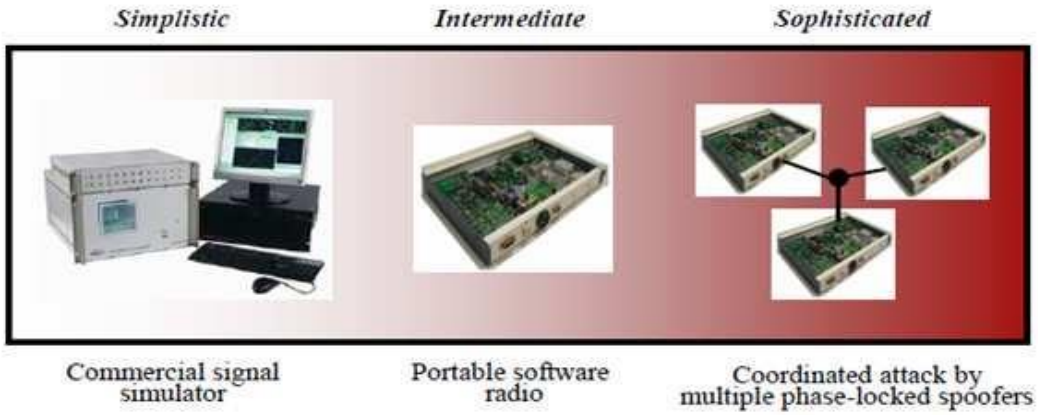
Jamming

- Denial of service attack
- Military jammers
  - “Friendly jamming”
  - Disabling of civilian GNSS while keeping military services intact
- Personal or Privacy Protection Devices (PPD)s
  - Sold over the internet starting at 30€
  - Usage is illegal in almost every country
- Motivation:
  - Turning off car anti-theft-systems
  - Bypassing pay-as-you-drive insurance
  - Withdrawing Fleet Management System
  - Protecting the privacy of parcel delivery agents from their employers

Spoofing

- Spoofing: transmission of fake GNSS signals with the intention of fooling a GNSS receiver into providing false Position, Velocity and Time (PVT)

- Different types of attacks
  - Meaconing: rebroadcasting a received signal
  - Simplistic attack
  - Intermediate attack
  - Sophisticated attack
- Spoofers exist:
  - SimSAFE from Spirent with GSS8000: >200k€



  - Proof-of-concept demonstrators

Spoofing attacks

Incidents

Spoofing attacks

- Successful demonstration of spoofing attack
  - on drone
  - on Yacht
  - on time of power grid

Conclusion

- **GNSS technology market grows rapidly, infiltrating new and expanding old spheres of application;**

- **With the latest improvements of global differential correction services and PPP technology we now witness the global shifting of GNSS developments focus to wide variety of services and mobility;**

- **With the GNSS solutions integrating deeply to our everyday life, new threats emerging and become more dangerous:**

- **GNSS service is often taken for granted**
  - **No real awareness of how fragile it is, despite many incidents**
  - **Most professional receivers do not detect jamming or spoofing events**
  - **Even though commercial jammers and spoofers are emerging**
  - **Despite of existing models of ionosphere, high level of solar activities still result in TEC anomalies and scintillation effects.**

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